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REPORT OF THE MEETING TO REVIEW THE PRELIMINARY ESTIMATES OF EASTERN TROPICAL PACIFIC DOLPHIN ABUNDANCE IN 1998 - JANUARY 21, 1999

By

Paula Olson and Tim Gerrodette

ADMINISTRATIVE REPORT LJ-99-03

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REPORT OF THE MEETING TO REVIEW THE PRELIMINARY ESTIMATES OF EASTERN TROPICAL PACIFIC DOLPHIN ABUNDANCE IN 1998 JANUARY 21, 1999

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BACKGROUND

The 1997 International Dolphin Conservation Program Act (Public Law 105-42) directed the National Marine Fisheries Service to determine if the tropical tuna purse seine fishery in the eastern tropical Pacific (ETP) is having a significant adverse impact on depleted dolphin stocks. As part this determination, Congress specified that dolphin population surveys be undertaken in 1998, 1999, and 2000 to generate new abundance estimates.

The first of these surveys was carried out from July 31 to December 9, 1998. The estimates of abundance based on the 1998 data will be part of the information that the Secretary of Commerce will use to make a preliminary finding on the adverse effect of the tuna fishery. The Secretary is mandated to reach a preliminary finding by March 31, 1999. The estimates of abundance will also be used to establish dolphin mortality limits under the International Dolphin Conservation Program Agreement when it comes into force.

On January 21, 1999, the Southwest Fisheries Science Center (SWFSC) convened a technical meeting to review the line-transect analysis of the 1998 data. The meeting was attended by recognized experts in line-transect theory and application, by representatives of the Inter-American Tropical Tuna Commission (IATTC), the Mexican government, and the Peruvian government, as well as scientists from the SWFSC (Appendix 1). This report will follow the order of topics discussed at the meeting (Appendix 2). A draft analysis of 1998 data was distributed at the meeting (Appendix 3). Figures and tables mentioned in this report refer to the draft analysis.

INTRODUCTION

Jay Barlow opened the meeting at 8:00 AM. Introductions of attendees were made all around, including Steve Buckland and Len Thomas participating from Scotland via conference telephone call. Barlow reminded the attendees that the purpose of the meeting was to review the line-transect analysis of the 1998 data and that discussion would be limited to the question of how to best handle the data collected on the 1998 survey. Other aspects of the tuna-dolphin issue would not be discussed. Barlow then turned the meeting over to Tim Gerrodette.

Given that this was a technical meeting and in the interest of time, Gerrodette dispensed with introducing the tuna-dolphin issue since all present were familiar with it. He also forwent reviewing the survey methods, which followed the standard procedures used by the SWFSC in the past 15 years and which were covered in the manuscript presented to attendees. The abundance of four stocks of dolphins, those believed to be most affected by the fishery, were estimated for this preliminary report. The estimated stocks were eastern spinner dolphins, northeastern offshore spotted dolphins, western-

southern spotted dolphins, and coastal spotted dolphins. Gerrodette proceeded to lead the group through the steps of his analysis of the 1998 data.

NATURE OF DATA

Strata

The survey was originally designed with three strata:

1) a coastal stratum, approximately from the coastline to a depth of 1000 meters and corresponding with the stock of coastal spotted dolphins
2) a core stratum, corresponding to the highest densities of the dolphins that most frequently interact with the fishery, in particular the stock of northeastern offshore spotted dolphins
3) an outer stratum, further offshore and to the south and roughly corresponding with the stocks of western-southern offshore spotted dolphins and whitebelly spinner dolphins (Figure 1).

The stock of eastern spinner dolphins is geographically centered in the core stratum, but is also found in the outer and coastal strata.

After the cruise, two changes were made to the stratification. The first change involved modifications to the boundary of the coastal stratum. The stratum boundary was originally drawn at the 1000 meter contour depth line. However, the ships surveying in the coastal stratum occasionally went outside the 1000 meter line, so the boundary was moved to include all coastal survey effort intended to be within the coastal stratum. The 1000 meter boundary was followed when possible, otherwise the boundary was drawn at six miles beyond the path of the vessel. Also, a boundary line was drawn across the mouth of the Gulf of California and the area inside the Gulf was included in the coastal stratum. Another modification split the coastal stratum into a north coastal stratum and a south coastal stratum at 5°N. With these changes, a total of four strata were used in the analysis: north coastal, south coastal, core, and outer.

The second post-cruise change in stratification affected the northern area of the core stratum. Originally, this portion of the core extended north to the U.S./Mexican border. Post-cruise, the core boundary was drawn at 25°N and the area was included in the outer stratum (Figure 2). The reasons for this change had to do with sampling and density. Due to bad weather in this area during the survey, the area was less sampled than the rest of the core; the amount of effort was more consistent with that in the outer stratum. Furthermore, the lower density of spotted and spinner dolphins in

this area (based on previous surveys) was consistent with that of the outer stratum. No spotted dolphins were seen in this area during the 1998 survey.

Gerrodette was queried on the difference in the area of the coastal strata after these changes. Gerrodette had not calculated it exactly, but said that the coastal stratum was slightly larger now.

Samples

The majority of the spotted and spinner dolphin sightings occurred in the core and coastal strata, as expected. A survey day consisted of on-effort searching and off-effort closing modes. One day's effort was considered one sample. The amount of effort each day varied, but was roughly 100 to 200 kilometers per day. Small amounts of effort on a day were combined with nearby transects.

Three ships participated in the survey. In response to questions, Gerrodette remarked that the tracklines shown in Figure 2 represented all ships. The three vessels surveyed in all three strata. The ship platforms were basically the same. Ten minutes to an hour was spent in closing mode when dolphins were sighted - a significant amount of time.

Table 1 details the area, length of transect effort, and number of sampling days per stratum. The spotted and spinner dolphin sightings included in this table are those detected in < Beaufort 6 and > 4 kilometers visibility.

Sighting Categories

Gerrodette explained that there are six sighting categories that contribute to the four dolphin stocks for which abundance estimates will be calculated. The sighting categories of dolphins produced by the survey do not correspond exactly to the stocks (Table 2). Not all sightings can be identified to the subspecies level. Estimates of spotters and spinners unidentified to the subspecies level must be incorporated into the stock estimates; they must be prorated. Unidentified dolphins must also be prorated.

The meeting broke into a question and comment period at this time. Gerrodette was asked where the whitebelly spinner dolphins were in the tables presented. He answered that the abundance of whitebelly spinners was not being estimated in this analysis. In response to another question, Gerrodette clarified that the totals shown in Table 2 were sightings prior to truncation.

Concern was expressed over the large number of unidentified dolphins. It was explained that the data collection procedure was conservative when determining species identification. The team in Scotland observed that the average school size of unidentified dolphins was small. Someone asked if the average school size was

different for different sighting categories. Gerrodette said yes, noting that the average school size for unidentified dolphins was <10 and the average school size for identified dolphins was >50. It was proposed that since the ships did not pursue schools sighted at a distance further than three miles from the trackline (standard procedure), perhaps this resulted in dolphins remaining unidentified. Buckland mentioned that most of the unidentified dolphins were seen close to the trackline. It was pointed out that a school may be sighted at a small perpendicular distance from the trackline but at a large radial distance from the ship. The comment was made that there could be a downward bias in the average school size of unidentified dolphins if unidentified schools sighted at long distances were underestimated.

As Gerrodette progressed toward presenting the analysis strategy, he reminded the group that the point of the meeting was to examine the preliminary abundance estimates. He stressed that the estimates are preliminary and draft, and some inconsistencies and errors exist in this first round. The final abundance estimates will correct these and will include suggestions and comments from this meeting. He requested that attendees offer their comments as first or second order: suggestions that could be realistically addressed in a one-two week time frame (due to a Department of Commerce deadline), and more substantial suggestions that could be addressed later.

Before proceeding with the analysis, Ken Burnham inquired whether the line-transect assumptions and data quality issues were all satisfactory. Gerrodette confirmed that these items have been addressed and will be covered in his forthcoming report. The angles measured by the azimuth rings and the distances measured by the reticle scales in the 25X binoculars have been checked against the ships' radar measurements. Estimating school size is not easily resolved, but using the helicopter to calibrate observers and using the mean of the observers' estimates reduces variability. The g(0) is assumed to be 1; the target species in this survey are not likely to be missed when they are on the trackline. Vessel attraction and avoidance is always an issue, but we have found that in most cases, the schools are detected before any reaction to the vessel occurs.

Buckland called attention to a "spike" at 2 km for spotted dolphins in the coastal stratum (Figure 3) and wondered if this could be due to a rounding of angles and distances. The suggestion was made to run a simulation to test whether such a spike was really expected. Concern was also expressed over a "spike" near the trackline. Gerrodette responded that he would like to return to this later in the meeting.

ANALYSIS STRATEGY

Gerrodette outlined his analysis strategy. In general, the analysis began with untruncated data and a single function. If there was a

long tail to the function, different truncations were tried until a reasonable histogram was produced. Once a truncation distance had been selected, several key and adjustment functions were used to model the detection function, and the model with the lowest AIC was selected.

The encounter rates and school sizes were estimated for each stratum and sighting category. Some sightings had to be pooled, however, for f(0) estimation. There were enough offshore spotted dolphins seen in the core and outer strata to fit detection functions separately for each of these strata. The coastal spotted dolphin sightings in the north coastal and south coastal strata were pooled. The eastern spinner sightings were pooled from all strata in order to fit a detection function. There were enough unidentified dolphin sightings to make abundance estimates in four strata.

Gerrodette solicited comments on the general strategy. Jeff Laake asked how the truncations were chosen and Gerrodette explained that he chose the fit that looked reasonable, usually at about four kilometers. Laake responded that he thought there was a school size issue present also. The suggestion was made to compare truncation results. Burnham commented that one doesn't want to look at a series of results and select the one with the most desirable outcome. He recommended choosing a reasonable "W" and sticking with it.

RESULTS

Eight Line-transect Analyses

Print-outs of eight line-transect analyses were distributed, and the results were also displayed on an overhead projector. The fit of eight detection functions were analyzed. Laake tabulated these analyses by sighting category and stratum for a simplified visual review by the group (see table below).

	Offshore Spotted	Coastal Spotted	Unid. Spotted	Eastern Spinner	Unid. Spinner	Unid. Dolphin
Core	#1	#1	#1	#4	#6	#5
Outer	#2			#4	#6	#7
Coastal	#3	#3	#3	#4	#6	#8

The idea was introduced that a detection function may change as a result of bird flock cues prevalent in some geographic areas. Buckland wondered if the detection function could be different for coastal spotted dolphins and offshore spotted dolphins. He thought the "spike" at the trackline in the coastal stratum histogram represented coastal spotted sightings and the "spike" at 2 km represented offshore spotted sightings. In any case, he suggested

exploring separate detection functions for offshore and coastal spotted dolphins seen in the coastal stratum.

The detection function analyses were discussed in the order that they were covered in the manuscript, beginning with coastal spotted dolphins seen in both the north and south coastal strata (Analysis #3, Figure 3).

Analysis #3, spotted dolphins in the two coastal strata (Figure 3). The group was troubled by the "spikes" at the trackline and at 2 km. The suggestion was made to look at the detection function of coastal spotted dolphins (*S.a. graffmani*) only, without offshores, in the coastal stratum. Since the Scotland team had the data and the Distance program at hand, they ran a real time analysis of these data. Buckland reported that the histogram of *graffmani* sightings did not look reasonable. It was suggested to try schools seen in < Beaufort 4. Buckland and Thomas ran another analysis and reported that this reduced the number of sightings by half but also eliminated the "spike" at 2 km. It also reduced the CV and increased the strip width from 1.2 km to 1.75 km. Several suggestions were offered: explore the inclusion of sightings in higher Beauforts; explore separating sighting categories; try reducing the Beaufort and then pooling the strata. It was opined that this last suggestion may not work because of seabird cues.

Gerrodette asked what the group thought about the encounter rate or the school size - were there issues with those? He thought the detection function had been addressed; he would try separating offshore spotted and coastal spotted dolphins. Buckland said he had an issue (for longer term consideration) with school size. He believed that a regression of the school sizes further indicated that the "spike" at 2 km was due to school size. Several participants mused on the source of the "spikes." Could it be the result of sightings made by the data recorder? If the tracklines were parallel to the coast, could there be some oceanographic features or inshore/offshore movement of dolphins that were a factor? In response to this comment, it was explained that the tracklines usually crossed inshore/offshore gradients, but perhaps that was not clear on the scale of the chart provided. Gerrodette was asked if he had explored other stratifications, such as Beaufort, and he said no, not yet. Laake observed that the school size estimate for unidentified spotted dolphins was higher than that for coastal or offshore spotted in this stratum. The expectation would be that the school size would be somewhere in the middle between coastal and offshore. It was pointed out that the sample size of unidentified spotted was small, only 17 sightings. Laake thought perhaps it was due to an artifact of the regression, but in any case, it was a second order issue.

Analysis #1, offshore spotted dolphins in the core stratum (Figure 4). There was agreement on this analysis that the detection function looked good. There was a large sample size for this analysis. Laake

returned to Analysis #3, with an idea: what about a school size regression with different intercepts on the same slope on a log scale? He reiterated that this was a second order issue.

Analysis #2, offshore spotted dolphins in the outer stratum (Figure 5). Although there were only 47 sightings in this stratum on which to estimate a detection function, there was agreement that the curve looked reasonable.

It was questioned which stock the offshore spotted sightings from the northeast corner would be attributed to if not included in this analysis (and in the western-southern stock of offshore spotted). Gerrodette replied that during the 1998 survey, no offshore spotted dolphins were sighted in this area. He agreed that a small part of the estimated abundance of offshore spotted dolphins in the outer stratum should be prorated to the northeastern offshore spotted stock, based on this area.

Burnham offered a longer-term suggestion of adding sub-stratification to the outer stratum in order to get an estimated encounter rate. This should have the effect of explaining the variability in this stratum. The idea was carried further with the suggestion to stratify post-survey by drawing a N-S line to create an E-W gradient.

Analysis #4, eastern spinner dolphins in three strata (Figure 6). There was a fairly large number of sightings in this sample. Several participants agreed that it would be worthwhile trying to stratify by geography for detection functions. Potential problems with doing this were mentioned, such as the small number of sightings in the coastal stratum.

Analysis #6, unidentified spinner dolphins in three strata. There were very few unidentified spinner dolphin sightings. Therefore, the unidentified spinners were pooled with the eastern, the abundance estimated, and then the numbers of eastern spinners subtracted.

Laake reasoned that the same truncation point should be used for unidentified and eastern spinners in this exercise (5 km was used for eastern and 4 km for unidentified) and Gerrodette agreed. Burnham remarked that since only a few unidentified data were added to the eastern data, it seemed reasonable to use the same form and the same width. The comment was made that including the eastern spinners may bias the detection function if detection functions were different for eastern and whitebelly spinners. It was suggested to include all spinners when estimating the detection function or to geographically apportion the unidentified. Gerrodette thought this was a good point.

After whitebelly spinners were mentioned, it was queried if there were other data available that could be used. Burnham said that if

identified (whitebelly) spinners and unidentified spinners had similar detection functions, then pooling would be acceptable. If the detection functions were not similar it would be problematic. He urged an exploration of the whitebelly spinner data.

Analysis #5, unidentified dolphins in the core area. The sample size was large and heterogeneous. There are many species of dolphin that may be included as unidentified (Table 5). The heterogeneity led to a long tail; Gerrodette asked for feedback on the long tail. It was recommended that the data be truncated at the ships' closing distance. Many participants agreed on truncating the data. Additionally, it was suggested that the abundance for unidentified dolphins be calculated the same way as was done for unidentified spinners: estimate the abundance of identified and unidentified together, then estimate the abundance of only the identified, and subtract to get an estimate of unidentified dolphin abundance.

Analysis #7, unidentified dolphins in the outer stratum. Gerrodette noted that the detection function was problematic since there was a "spike" in the tail.

Participants reiterated their concern over the large number of unidentified dolphins. A discussion began about the nature of unidentified dolphin sightings when the question was raised about why there were so many unidentified sightings. Many dolphins flee from ships in the ETP. Sometimes dolphins are seen at a far radial distance (even if close to the trackline) and then are unable to be relocated. High swell and high Beaufort also reduce the ability to relocate and to observe dolphins. It was proposed to have the field personnel record what they thought were possible ID's. Gerrodette responded that this was already done: observers record probable and possible species ID's whenever possible. These sightings have already been upgraded and included as identified schools when observers made a "probable" identification. Gerrodette thought that perhaps in the future the helicopter could be used to examine distant schools that were unidentified from the ship.

Ideas were offered on how to handle the unidentified dolphin data. The suggestion was made to stratify by radial distance. It was mentioned that SWFSC scientists had not yet quantified at what distance in the 25X binoculars dolphins can be identified. Truncating data at that distance might be an option.

Another idea involved assigning the unidentified dolphins to stocks on a school-by-school basis instead of estimating their overall abundance. Rare categories would not be eliminated, but would be assigned at the level of the sighting. It was commented that although this idea was interesting, it could not be addressed in a two week time frame.

Concern was expressed that the unidentified dolphins did not meet the assumption of uniform distribution. One way around this, Buckland suggested, was to pool the pure unidentified schools with all the categories of identified dolphins and then find the difference, as had been mentioned earlier (Analysis #5).

Analysis #8, unidentified dolphins in the coastal stratum. This detection function had a "spike" at the trackline and a long tail.

It was proposed that the "spike" at trackline in both this analysis and the analysis of spotted dolphins in the coastal stratum might be due to the pattern observers use to scan on the 25X. Usually the visual team is on-effort for a very short time before detecting animals in the high density area near the coast. If the observers' scans start forward of the ship near the trackline, most sightings would be detected there.

It was suggested that the same Beaufort state truncation should be used for this analysis as was used for the identified spotted dolphins in the coastal stratum.

Despite the problematic nature of unidentified dolphin detection functions in the analysis presented, it was noted that numerically the contribution of unidentified dolphins was not large.

Mixed schools. Gerrodette brought up that the species of interest (spotters and spinners) often occur in mixed schools. So far, they have been treated as separate entities for detection functions. He suggested another approach that would pool spotted and spinners for the detection function of mixed schools and then separate them for school size and encounter rate. Laake suggested apportioning the dolphins that occur in mixed schools by the proportion that they appear in the mix. There was agreement that this idea was worth exploring.

Laake suggested fitting detection functions for pure and for mixed schools and then estimating abundance. It was put forth that one species might be more detectable and so would make an otherwise less detectable species more visible in a mixed school. It was mentioned again that seabird flocks should be considered when looking at detection functions. Bird associations vary more between geographic strata than between species in a given geographic area. Burnham said that the Distance software currently doesn't have that kind of sophistication for detectability.

Proration of Unidentified Spotted and Spinner Dolphins

Unidentified spotted dolphins (Table 3). The proration of unidentified spotted from the south coastal stratum to the western-southern stock had been overlooked - a potential error. It was observed that since there were not any sightings of unidentified spotted dolphins in the southern coastal stratum that it did not

matter. Burnham thought the approach looked good. Laake agreed, although he said that the abundance estimate may change because of detection function changes discussed earlier.

Unidentified spinner dolphins (Table 4). This proration was based on encounter rate rather than abundance, because there was not enough time to estimate abundance of the other spinners (whitebelly and Central American). This is inconsistent with the unidentified spotted proration which was based on abundance.

A request was made to see the remainder of the spinners spelled out as whitebelly and Central American spinners. Gerrodette said he would include this in the text of his manuscript.

It was recommended that since pure and mixed schools were used in the abundance estimate for unidentified spinners, the proration should be consistent and include mixed schools as well when calculating the proportions.

It was suggested that it might be better to use densities rather than school fractions. Approximate densities could be calculated for spinners by multiplying the total number of schools by average school size.

Proration of Unidentified Dolphins

Table 5 shows all the possible species that could be unidentified dolphins. The proration was based on the proportion of pure schools. The table represents pure schools from all strata. As noted before for unidentified spinner dolphins, an improved proration factor would be based on abundance, not encounter rates.

Table 6 shows the proration of unidentified dolphins to the four dolphin stocks. There is an error in that unidentified dolphins in the north and south coastal strata were only apportioned to northeast offshore and coastal spotted dolphin stocks, instead of to all possible species that might be classified as unidentified dolphins. This will be corrected.

There were several suggestions, including calculating densities for the various dolphin species as was described for the non-eastern spinners. Laake proposed using pure and mixed schools, within the truncation distance, by strata.

The observation was made that if the size of spotted groups were different in pure schools and mixed schools, then this would be problematic unless it was attended to. Perhaps using an average group size would be better.

Gerrodette agreed, and in response to the recommendations that had been offered, detailed four changes he would incorporate into his proration of unidentified dolphins: 1)include pure and mixed

schools, 2)calculate factors by strata, 3)include truncation, and 4)use school size or, ideally, abundance.

Tables 7 and 8 show the estimated abundances of the four dolphin stocks and their components, sources, and CV's. Gerrodette reiterated that the estimates were preliminary and would be revised in response to comments offered at this meeting.

CONCLUSION

As the discussion over prorating unidentified dolphins wound down, general comments were offered.

It was pointed out that CV's could not be combined in the way that they were in Table 7 since it was not possible to assume independence in all sources. An alternative method which includes correlations between estimates will be used in producing the final estimates.

The importance of consistency with past methods of estimating the abundance of ETP dolphins was discussed. Gerrodette agreed that it was important that the present (1998) data and MOPS (1986-90) data be analyzed in similar ways, in particular in regard to such issues as bias correction and proration of unidentified sightings. It was mentioned that re-analysis of past data may be necessary.

As the meeting drew to a close, Barlow thanked everyone for attending, and commended Gerrodette on the amount of work completed in such a short time following the end of the 1998 survey. The meeting ended shortly after 3:00 PM.

Draft copies of this report were sent to all attendees for revision. Comments on the report were received from February 4 through February 22. Some attendees also submitted further comments on the analysis strategy, via email. The Marine Mammal Commission submitted comments on Gerrodette's draft analysis (Appendix 3) via letter.

APPENDIX 1

Attendees

Abundance Review Meeting 1/21/99

Southwest Fisheries Science Center, USA

Dr. Tim Gerrodette (Convener)

Dr. Jay Barlow (Chair)

Ms. Paula Olson (Rapporteur)

Invited Technical Reviewers

Dr. Stephen Buckland (via conference call) - U. of St. Andrews, SCOTLAND

Dr. Ken Burnham - Colorado Cooperative Fish & Wildlife Research Unit, USA

Dr. Jeff Laake - National Marine Fisheries Service, USA

Dr. Len Thomas (via conference call) - U. of St. Andrews, SCOTLAND

Other Technical Reviewers

Dr. Robin Allen - Inter-American Tropical Tuna Commission

Mr. Alejandro Anganuzzi - Indian Ocean Tuna Commission

Dr. Karin Forney - Southwest Fisheries Science Center, USA

Dr. Martin Hall - Inter-American Tropical Tuna Commission

Ms. Cleridy Lennert - Inter-American Tropical Tuna Commission

Mr. Miguel Rabí - Instituto del Mar del Peru, PERU

Dr. Lorenzo Rojas - Instituto Nacional de la Pesca, MEXICO

Mr. Luis Vicente - Instituto Nacional de la Pesca, MEXICO

Southwest Fisheries Science Center Observers

Dr. Lisa Ballance
Mr. John Brandon
Dr. Bob Brownell
Mr. Jim Carretta
Dr. Sue Chivers
Ms. Katie Cramer
Dr. Andy Dizon
Ms. Meghan Donahue
Dr. Sergio Escorza
Dr. Paul Fiedler
Ms. Kathy Hough
Mr. Douglas Kinzey
Dr. Sarah Mesnick
LT. Anne Nimershiem
Mr. Peter Perkins
Dr. Bill Perrin
Mr. Wayne Perryman
Dr. Barbara Taylor

APPENDIX 2

REVIEW OF PRELIMINARY ESTIMATES OF 1998 ETP DOLPHIN ABUNDANCE

AGENDA

Thursday, January 21, 1999

Introduction and Objectives of Meeting

Nature of Data

- Strata
- Samples
- Sighting categories

Analysis Strategy

- Encounter Rate
- School Size
- Detection Function
  - Pooling
  - Truncation
  - Model selection

Results

- Eight line transect analyses
- Proration of unidentified spotted and spinner dolphins
- Proration of unidentified dolphins

APPENDIX 3

DRAFT

DO NOT CITE WITHOUT PERMISSION OF AUTHOR

PRELIMINARY ESTIMATES OF 1998 DOLPHIN ABUNDANCE FOR THE MAIN STOCKS OF DOLPHINS THAT INTERACT WITH THE TROPICAL TUNA PURSE-SEINE FISHERY IN THE EASTERN TROPICAL PACIFIC OCEAN

Tim Gerrodette

Southwest Fisheries Science Center

La Jolla, California

January 20, 1999

INTRODUCTION

The 1997 International Dolphin Conservation Program Act (Public Law 105-42) directed the National Marine Fisheries Service to determine if the tropical tuna purse-seine fishery in the eastern tropical Pacific (ETP) is having a significant adverse impact on depleted dolphin stocks. As part of this determination, Congress specified that dolphin population surveys be undertaken in 1998, 1999, and 2000 to generate new abundance estimates. On December 17-18, 1997, the Southwest Fisheries Science Center (SWFSC) convened a technical meeting in La Jolla, California, to discuss the design of the *Stenella* Population Abundance Monitoring (SPAM) surveys. The participants agreed that methods similar to those used on surveys from 1986-90 should be continued on the 1998-2000 surveys, but, based on updated information about spotted and spinner dolphin distributions, that the study area should be changed slightly. A stratified survey effort was recommended, along with a number of other small changes. The recommendations of the participants were included in the 1998 survey.

1998 SURVEY METHODS

The 1998 SPAM survey was carried out from July 31 to December 9, 1998. Three ships participated in the survey: NOAA Ships *David Starr Jordan* and *McArthur*, and the *Endeavor* from the University of Rhode Island. All ships are oceanographic research vessels. Although the ships range in length from 52m to 57m, observer height above the sea surface is nearly the same on all vessels (10.7m, 10.4m and 10.4m, respectively). Observers rotated among vessels during the survey.

Searching effort was stratified into 3 areas: a coastal stratum, approximately from the coastline to a depth of 1000m; a core stratum, corresponding to the highest densities of the dolphin stocks that most frequently interact with the fishery; and an outer stratum further offshore and to the south (Fig. 1). Effort in the core stratum was approximately 3 times the effort in the outer stratum per square unit area. The geographic strata roughly correspond to the three stocks of spotted dolphins: coastal=coastal; core=northeastern spotted; and outer=western-southern spotted. The stock of eastern spinners is geographically centered in the core stratum, but is also found in the outer and coastal strata.

Methods of collecting data suitable for line-transect analysis followed previous protocols and can be briefly described as follows. A visual watch for cetaceans is conducted on the flying bridge from dawn to dusk, in weather up to Beaufort 6, by a team of three observers who rotate every 40 minutes. Each observer stands watch for 2 hours, then has 2 hours rest. Two observers search with pedestal-mounted 25x150 binoculars, scanning the 180° forward of the ship. The 25X binoculars are fitted with azimuth rings and reticles for angle and distance measurements. The third observer acts as data recorder and searches by eye. When a marine mammal is sighted the angle and distance to the sighting are measured and recorded in a portable computer. The team goes "off-effort" and into a "closing mode" in which the ship is directed to leave the transect line and approach the animal(s) sighted. The observers identify the sighting to species or subspecies (if possible) and make group size estimates of the animal(s) sighted. Every observer team has at least one observer highly experienced in the field identification of marine mammals. Observers discuss distinguishing field characteristics in order to obtain the best possible identification, but they estimate group sizes

independently. The computer is connected to the ship's GPS system and records the positions at the beginning and end of each search effort segment.

ANALYSIS

Effort and stratification

In general, the cruise was carried out as designed. Difficulty in obtaining research clearance from various countries in the study area was the main cause of adjustments to the tracklines during the cruise. Despite these difficulties, a good geographic distribution of sampling was obtained. The ships spent a total of approximately 330 days in the study area and achieved over 40,000 km of transect effort.

Two kinds of post-cruise stratification were made. First, slight changes were made to the coastal stratum boundary so that coastal survey effort occurred entirely with the stratum; also, the coastal stratum was divided into 2 parts with the dividing line at 5N. Second, the northern part of the core stratum was ended at 25N instead of extending to the U.S.-Mexican border (Fig. 1). There were two reasons for this change: (1) due to bad weather, the northern corner of the original core stratum was undersampled; and (2) few spotted or spinner dolphins occur in this area, so that it is more properly sampled as part of the outer or low-density stratum. With these changes, there were 4 strata used in the analysis: core, outer, north coastal and south coastal (Fig. 1). Areas for the 4 strata are given in Table 1.

The analysis used search effort and sightings that occurred in conditions of Beaufort sea state 5 or less, and with visibility of 4 km or more. Search effort and sightings within a day were summed; thus, one day of search effort was considered the sampling unit. Ships moved at night, providing some independence among samples. Due to a variety of factors, numbers of kilometers searched each day were not equal. To reduce heterogeneity among sampling units, effort < 50 km/day in offshore areas, and < 30 km/day in coastal areas, was combined with effort on other days close in space and time. A few transects remained small because there was no nearby effort with which they could be combined. After combining effort in this way, there was a total of 291 samples distributed among the 4 strata as shown in Table 1; total length of search effort in each stratum is also shown in Table 1.

Sightings

Data files containing sighting and effort information were produced by the program WinCruz in the standard SWFSC format for marine mammal sighting data. Data were checked and edited following standard procedures, but, due to time constraints, editing was completed for spotted and spinner dolphins only. In this analysis, only three stocks of spotted dolphins (coastal, northeastern offshore, and western/southern offshore) and one stock of spinner dolphins (eastern) are considered. These are the main stocks affected by the tuna fishery.

Six sighting categories contributed to the abundance estimates of the four dolphin stocks:

Offshore spotted dolphin	(Stenella attenuata attenuata)
Coastal spotted dolphin	(Stenella attenuata graffmani)
Unidentified spotted dolphin	(Stenella attenuata unid. subsp.)
Eastern spinner dolphin	(Stenella longirostris orientalis)

Unidentified spinner dolphin (Stenella longirostris unid. subsp.)
Unidentified dolphin

The number of on-effort sightings of each of these 6 sighting categories in each of the 4 strata is given in Table 2.

A sighting consisted of a school of dolphins; therefore, to estimate numbers of animals, estimates of group size are also needed. School size was the mean of the observer's best estimates. In the case of mixed schools, school size was calculated by taking the mean proportion of the species in question times the school size.

Proration of unidentified sightings

Not all sightings could be identified to stock level. To estimate stock abundance, these unidentified sightings have to be prorated to stock. Simple ratios of identified sightings provided the basis for proration in these preliminary estimates. The abundance of the unidentified dolphin category was estimated, and the abundance prorated to stocks according to the proportion of identified sightings. There were 3 kinds of unidentified sightings that had to be prorated to the following stocks: unidentified spotted dolphins, to NE offshore spotted, WS offshore spotted, and coastal spotted; unidentified spinner dolphins, to eastern spinner dolphins; and unidentified dolphins, to all 4 stocks. The unidentified spotted and spinner sightings had a relatively simple ratio based on relative abundance (Tables 3 and 4). The proration of unidentified dolphins was more complicated because this category includes many possible species (Table 5). The fraction of all identified schools that were offshore spotted or eastern spinner (0.163 and 0.042, Table 5) were used to apportion the abundance estimate of unidentified dolphins (Table 6).

Abundance estimation

Data were extracted and formatted for import into Distance using a Fortran program written for the purpose. Abundance estimation was carried out using Distance, version 3.5, Release 4. Estimates of encounter rates and expected schools sizes (using bias correction unless it resulted in an increase in expected school size) were always based on data within a stratum only. Estimates of f(0) had to pool sightings in some cases in order to have sufficient sample size. Pooling for f(0) estimation is discussed by stock in the Results section.

Total abundance estimates for each stock were estimated by adding the appropriate sub-estimates. The CVs of the total estimate were estimated by combining the separate CVs assuming independence.

RESULTS

Coastal spotted dolphins

All sightings of coastal spotted dolphins occurred with the 2 coastal strata. Within the combined northern and southern coastal strata, sightings of all spotted dolphins were used to estimate a coastal detection function (DF) (Fig. 3, Analysis #3). Abundance estimates for each of the three sighting categories of spotted dolphins found in the coastal area (coastal, offshore, and unidentified) used this pooled DF together with estimated encounter rate

(ER) and expected school size (ESS) for each category. This gave an estimate of 96,900 coastal spotted dolphins. Additional coastal spotted dolphins were estimated from the proration of unidentified spotted sightings (40,100) and unidentified dolphin sightings (6,200) in the coastal stratum. The total estimate of abundance for this stock was 143,196, with a CV of 0.321 (Tables 7 and 8).

Northeastern offshore spotted dolphins

The core stratum includes most of the area where the northeastern (NE) stock of offshore spotted dolphins is found. Within the core area, it was assumed that all sightings of spotted dolphins not identified to stock were of the NE stock. There were sufficient sightings within the core stratum to obtain an abundance estimate solely from sightings within this stratum (Fig. 4, Analysis #1). Additional NE offshore spotted dolphins are found in the north coastal stratum. Within this stratum, abundance of offshore spotted dolphins was based on a pooled DF for all spotted dolphin sightings in the coastal stratum, as described above (Fig. 3), and ER and ESS for offshore sightings. Additional NE offshore spotted dolphins were estimated from the proration of unidentified spotted sightings in the coastal stratum and of unidentified dolphins in both the coastal and core strata (Table 7). The total estimate of abundance for this stock was 786,895, with a CV of 0.166 (Table 8).

Western/southern offshore spotted dolphins

The outer stratum includes the area of the western/southern (WS) stock of offshore spotted dolphins. There were sufficient sightings within the outer stratum to obtain an abundance estimate solely from sightings within the stratum (Analysis #2). Fig 5 gives details of the detection function. Additional WS offshore spotted dolphins were estimated from the proration of unidentified dolphin sightings in the outer stratum (Table 7). The total estimate of abundance for this stock was 616,121, with a CV of 0.310 (Table 8).

Eastern spinner dolphins

Eastern spinner dolphins are found in the north coastal, core and outer strata. All eastern spinner sightings were pooled for the DF estimate (Fig. 6, Analysis #4), while ER and ESS were stratified. The sum of the stratified estimates of identified eastern spinners was 640,100 animals (Table 7). Additional eastern spinner dolphins were estimated from the proration of unidentified spinner abundance within each stratum (269,500) and from the proration of unidentified dolphin abundance within each stratum (6,000) (Table 7). The total estimate of abundance for this stock was 915,542, with a CV of 0.217 (Table 8).

Unidentified spotted dolphins, unidentified spinner dolphins, and unidentified dolphins

As described above, estimates of abundance for these unidentified categories were carried out and the results apportioned to various stocks. The estimation of unidentified spotted dolphins in the coastal stratum is shown in Analysis #3 and the proration in Table 3. Unidentified spinner dolphins in each stratum were estimated by estimating a combined eastern

spinner/unidentified spinner category (Analysis #6), and then subtracting the results for eastern spinners (Analysis #4). Proration of unidentified spinners is shown in Table 4. There were sufficient sightings of unidentified dolphins to make stratified estimates for the core, outer and combined north and south coastal strata (Analyses #5, #7, #8). Proration of these estimates is shown in Table 6.

Table 1. Eastern tropical Pacific study area, survey effort, samples, and sightings of spotted and spinner dolphins for the four strata of search effort.

	Core	Outer	No. Coastal	So. Coastal	Total
Area (1000km^2)	5773.6	15172.5	539.3	168.7	21654.1
Effort (km)	18623	16838	4161	489	40113
Samples (transect days)	131	109	44	7	291
Spotted sightings	177	47	97	4	325
Spinner sightings	89	38	27	0	154

Table 2. Number of on-effort sightings of 6 sighting categories by stratum.

	Offshore spotted	Coastal spotted	Unid. spotted	Eastern spinner	Unid. spinner	Unid. dolphin
Core	165	0	12	79	8	138
Outer	47	0	0	8	6	78
No. Coastal	27	49	23	13	9	78
So. Coastal	2	2	0	0	0	4

Table 3. Proration of unidentified spotters.

	Unid. Spotted	**Coastal Spotted**		**NE Spotted**		**W-S Spotted**	
	$\hat{N}_{unid\ spotter}$	$Fraction_{coastal}$	$\hat{N}_{usp}$	$Fraction_{NE}$	$\hat{N}_{usp}$	$Fraction_{W\text{-}S}$	$\hat{N}_{usp}$
core							
outer							
N Coastal S Coastal	71,414	96,871 / (75,497 + 96,871) = 0.562	40,135	75,497 / (75,497 + 96,871) =0.438	31,279		

Table 4. Proration of unidentified spinners to Eastern spinners.

	Unid Spinner		**Eastern Spinner**
	$\hat{N}_{unid\ spinner}$	ESpin Fraction	$\hat{N}_{usp}$
core	61,770	88/90 = 0.98	60,535
outer	449,320	9/24 = 0.375	168,495
N Coastal	73,540	18/33 = 0.55	40,447

Table 5. Calculation of fractions to use in proration of unidentified dolphins to offshore spotted and Eastern spinner sighting categories in the offshore and core sampling strata.

Sighting code	Sighting category	No. schools (pure)	from unid	Total n	n/1053
2	***Stenella attenuata* (offshore)**	**135**	**37**	**172**	**0.163343**
6	*Stenella attenuata graffmani*	57		57	0.054131
90	*Stenella attenuata* (unid. subsp.)	37		0	0
10	***Stenella longirostris orientalis***	**34**	**10**	**44**	**0.041785**
3	*Stenella longirostris* (unid. subsp)	12		0	0
0	*Stenella longirostris* hybrid	5		0	0
88	*Stenella longirostris centroamericana*	3		3	0.002849
11	***Stenella longirostris* hybrid**	**2**	**7**	**9**	**0.008547**
18	*Tursiops truncatus*	233		233	0.221273
13	*Stenella coeruleoalba*	201		201	0.190883
17	*Delphinus delphis*	137		137	0.130104
21	*Grampus griseus*	67		67	0.063628
15	*Steno bredanensis*	46		46	0.043685
16	*Delphinus capensis*	38		38	0.036087
5	*Delphinus* sp.	15		15	0.014245
32	*Feresa attenuata*	14		14	0.013295
22	*Lagenorhynchus obliquidens*	8		8	0.007597
25	*Lagenorhynchus obscurus*	8		8	0.007597
26	*Lagenodelphis hosei*	0			0
31	*Peponocephala electra*	0			0
		1053			

Table 6. Proration of unidentified dolphins to the four dolphin stocks.

	Unid. dolphin	NE offsh. spot		WS offsh. spot		Coastal spot		East. spinner	
	$\hat{N}_{unid\ dolphin}$	f	$\hat{N}_u$	f	$\hat{N}_u$	f	$\hat{N}_u$	f	$\hat{N}_u$
Core	40,274	.163	6574					.042	1683
Outer	93,063			.163	15,201			.042	3889
North coastal	10,593	.438	4640			.562	5953	.042	443
South coastal	422	.438	185			.562	237		

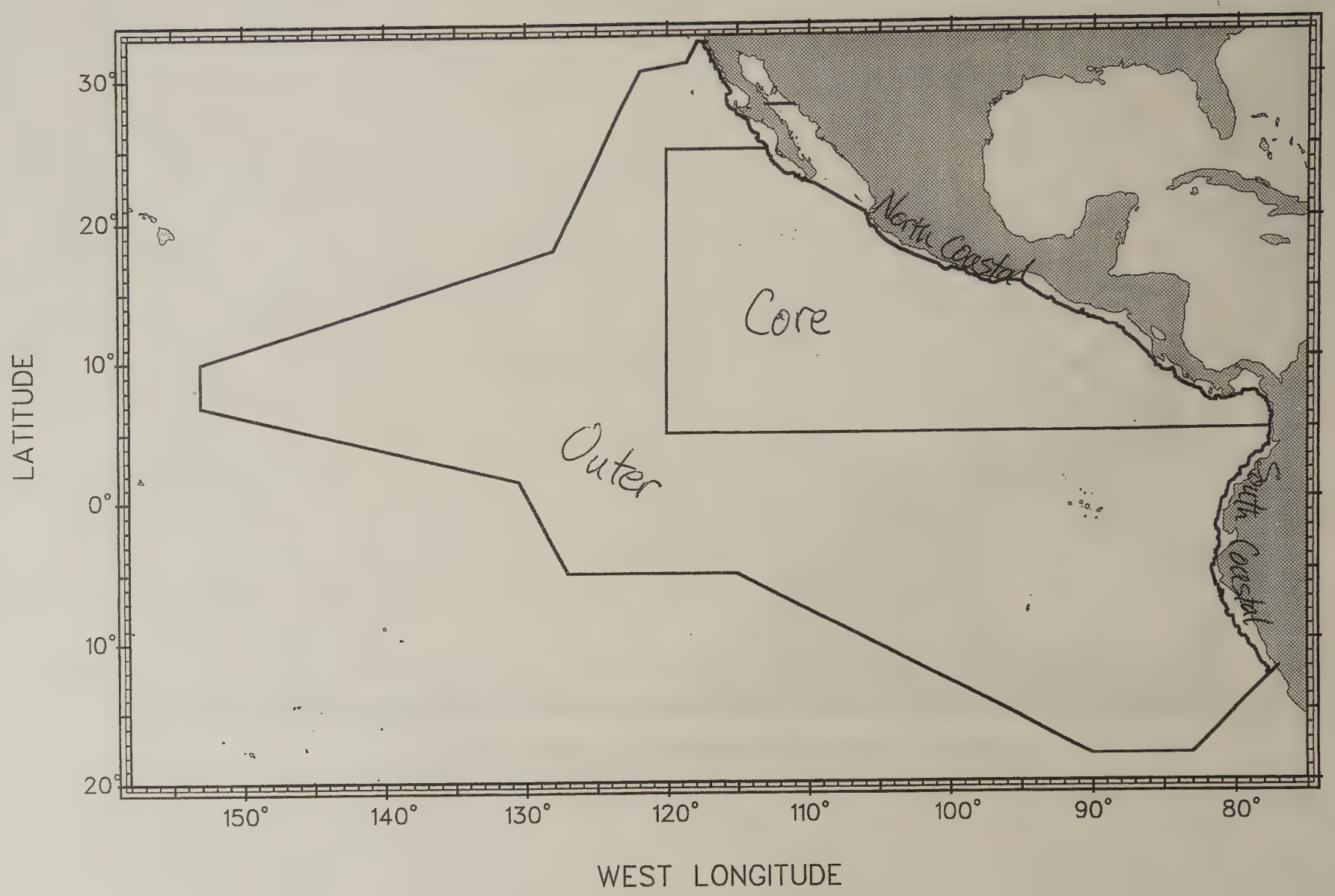
Table 7. Sources of estimates and CVs for each component of abundance, by stratum, stock, and level of identification.

Level of		Coastal spotted		NE offshore spotted		WS offshore spotted		Eastern spinner	
Identification	**Source of estimate**	N	CV	N	CV	N	CV	N	CV
Stock	identified in core stratum			668720	0.186			443580	0.337
	identified in outer stratum					600920	0.318	102640	0.725
	identified in coastal stratum	96871	0.411	75497	0.527			93830	0.488
Species	unid. spinner in core stratum							60535	0.252
	unid. spinner in outer startum							168495	0.563
	unid. spinner in N. coastal stratum							40447	0.360
	unid. spotter in coastal stratum	40135	0.568	31279	0.568				
Dolphin	unid. dolphin in core stratum			6574	0.186			1683	0.253
	unid. dolphin in outer stratum					15201	0.318	3889	0.378
	unid. dolphin in coastal stratum	6190	0.320	4825	0.320			443	0.319
	Total	143196	0.321	786895	0.167	616121	0.310	915542	0.217

Table 8. Abundance estimates for eastern tropical Pacific spotted and spinner dolphins in thousands of animals. N_{ID} is the estimate based only on identified sightings. N_{usp} represents additional animals from a pro-rated abundance estimate based on spinner or spotter sightings that were identified to species but not to subspecies or stock. N_u represents additional animals from a pro-rated abundance estimate based on unidentified dolphin sightings. N represents total abundance estimates, a sum of the other estimates. CV, N_L and N_U represent, respectively, the CV and the lower and upper 95% confidence limits of the total abundance estimate.

	N_{ID}	N_{usp}	N_u	N	%CV	N_L	N_U
Coastal spotted	96.9	40.1	6.2	143.2	32.1	77.5	264.5
Northeastern offshore spotted	744.2	31.3	11.4	786.9	16.6	570.1	1086.2
Western-southern offshore spotted	600.9		15.2	616.1	31.0	340.4	1115.1
Eastern spinner	640.1	269.5	6.0	915.6	21.7	601.6	1393.4

Fig. 1


30°
20°
10°
0°
10°
20°
150°
140°
130°
120°
110°
100°
90°
80°
LATITUDE
WEST LONGITUDE
North Coastal
Core
Outer
South Coastal

DRAFT

Fig. 2

SPAM 1998 STRATIFIED SEARCH EFFORT

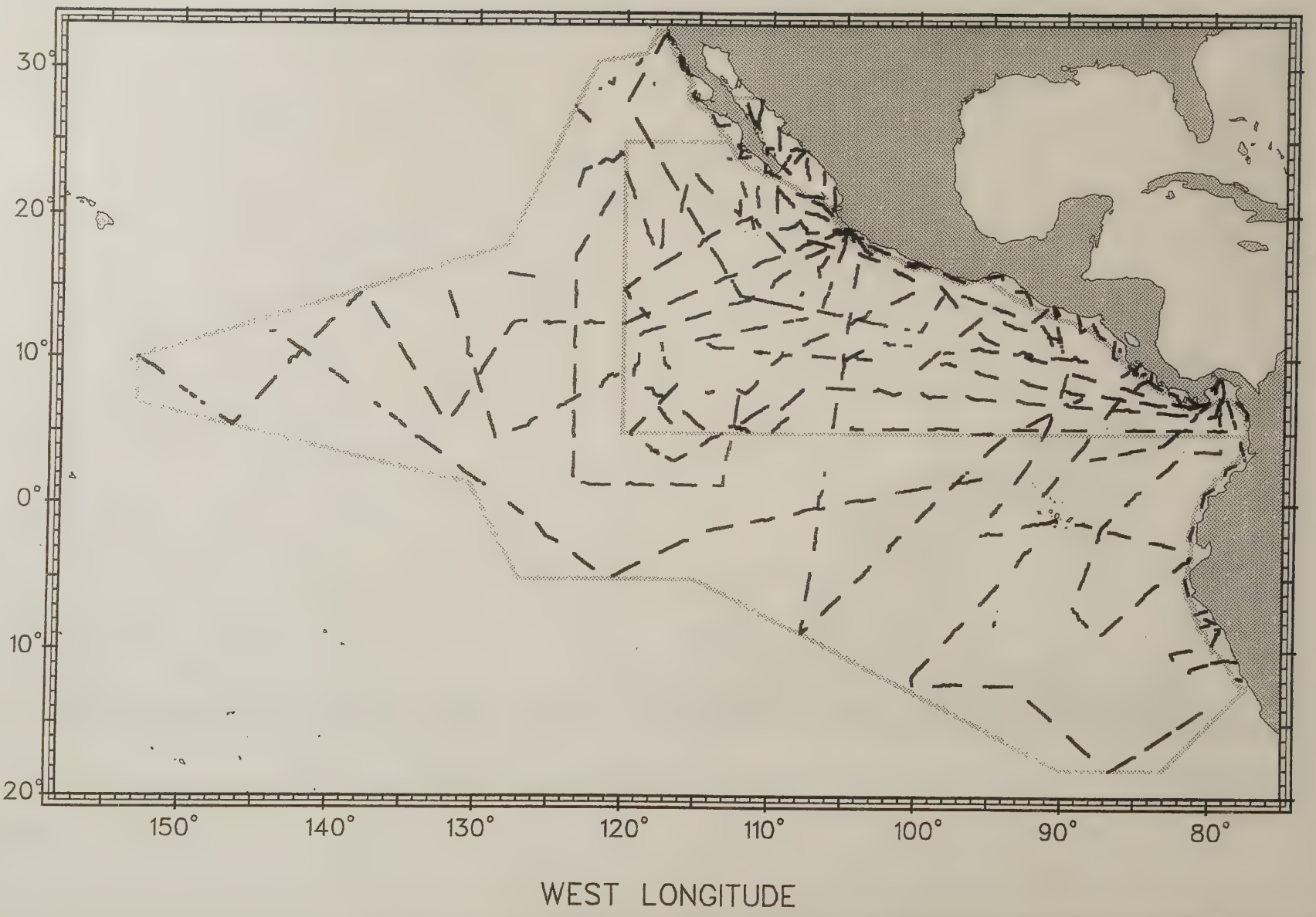


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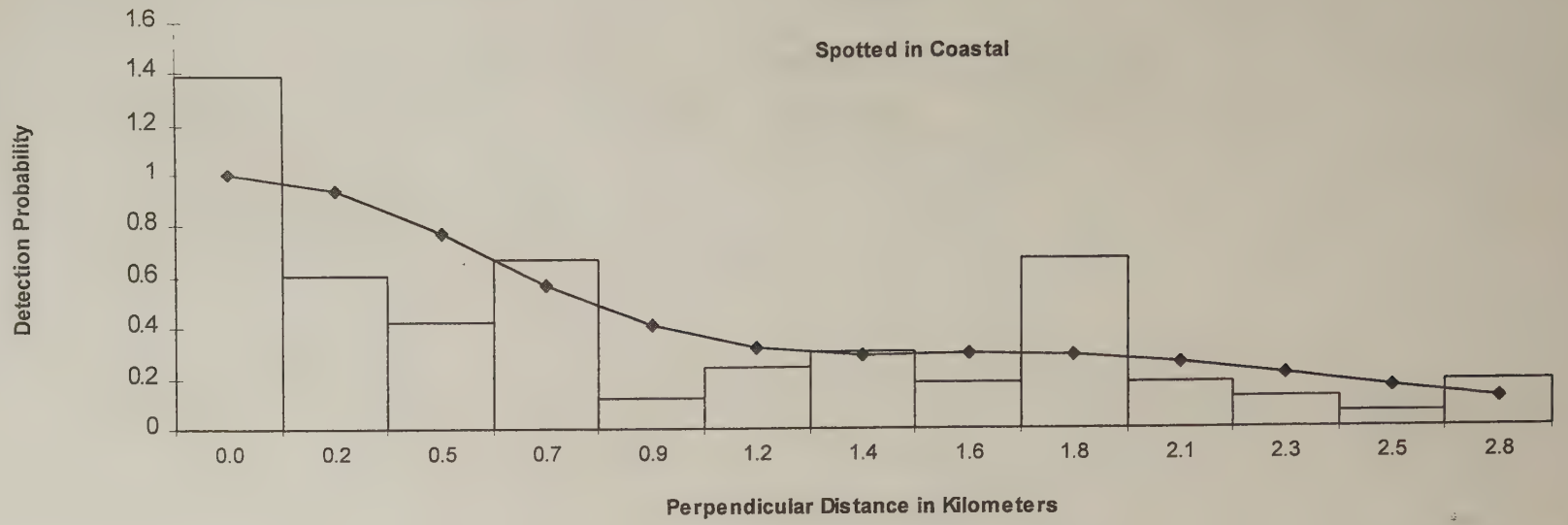
Fig. 3. Estimated detection function for spotted dolphins in the coastal stratum (north and south).



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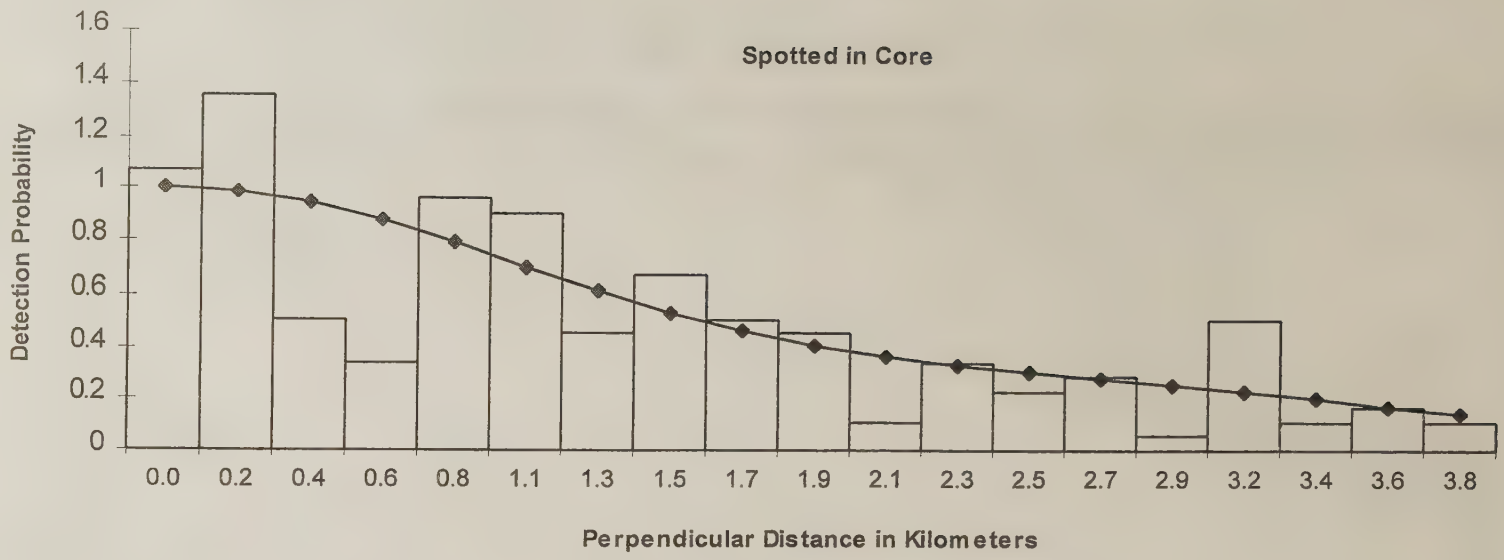
Width : 3.000000
observations: 85

Model
Half-normal key, k(y) = Exp(-y**2/(2*A(1)**2))
Cosine adjustments of order(s) : 2, 3

Parameter	Point Estimate	Standard Error	Percent Coef. Of Variation	95 Percent Confidence Interval
A(1)	1.418	0.1416	9.98	
A(2)	0.2636	0.1604	60.85	0.63482
A(3)	0.1845	0.1503	81.50	1.1193
F(0)	0.84295	0.12078	14.33	

Fig. 4. Estimated detection function for spotted dolphins in the core stratum.



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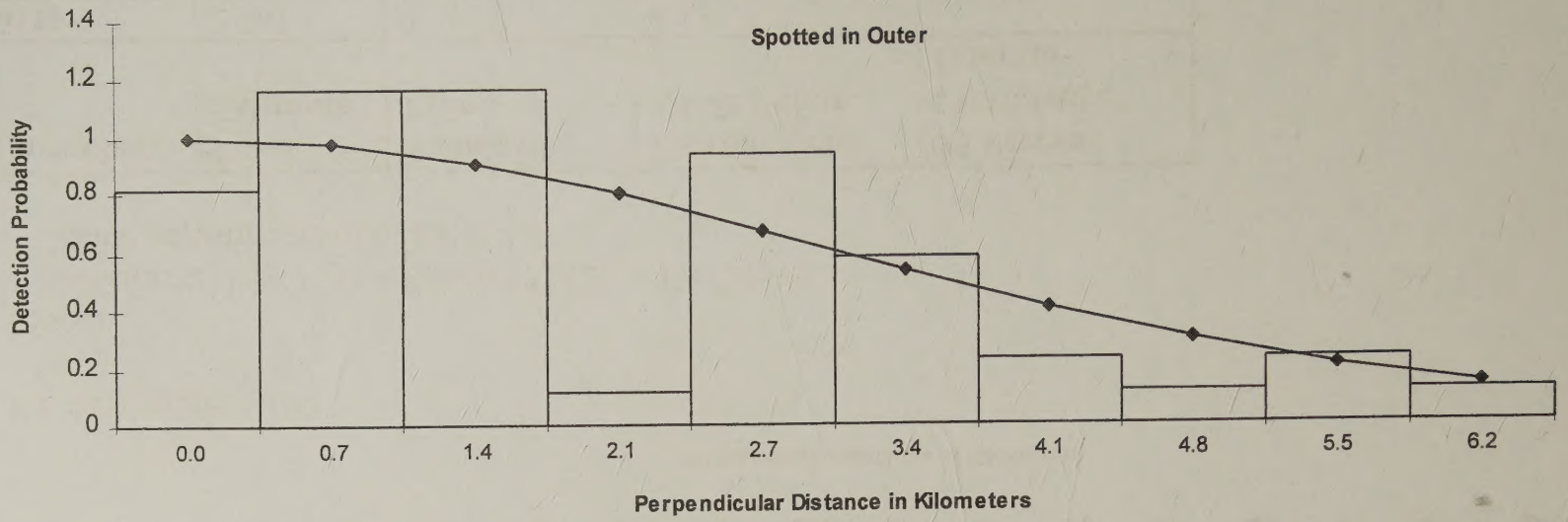
Width : 4.000000
observations: 162

Model
Half-normal key, k(y) = Exp(-y**2/(2*A(1)**2))
Cosine adjustments of order(s) : 2

Parameter	Point Estimate	Standard Error	Percent Coef of Variation	95 Percent Confidence Interval
A(1)	1.924	0.1543	8.02	0.42474 0.63546
A(2)	0.2044	0.1110	54.33	
f(0)	0.51952	0.53128E-01	10.23	

Fig. 5. Estimated detection function for spotted dolphins in the outer stratum.



Width : 6.870000
observations: 47

Model
Half-normal key, k(y) = Exp(-y**2/(2*A(1)**2))

Parameter	Point Estimate	Standard Error	Percent Coef of Variation	95 Percent Confidence Interval
A(1)	3.091	0.4235	13.70	0.21008
				0.33444
f(0)	0.26506	0.30715E-01	11.59	

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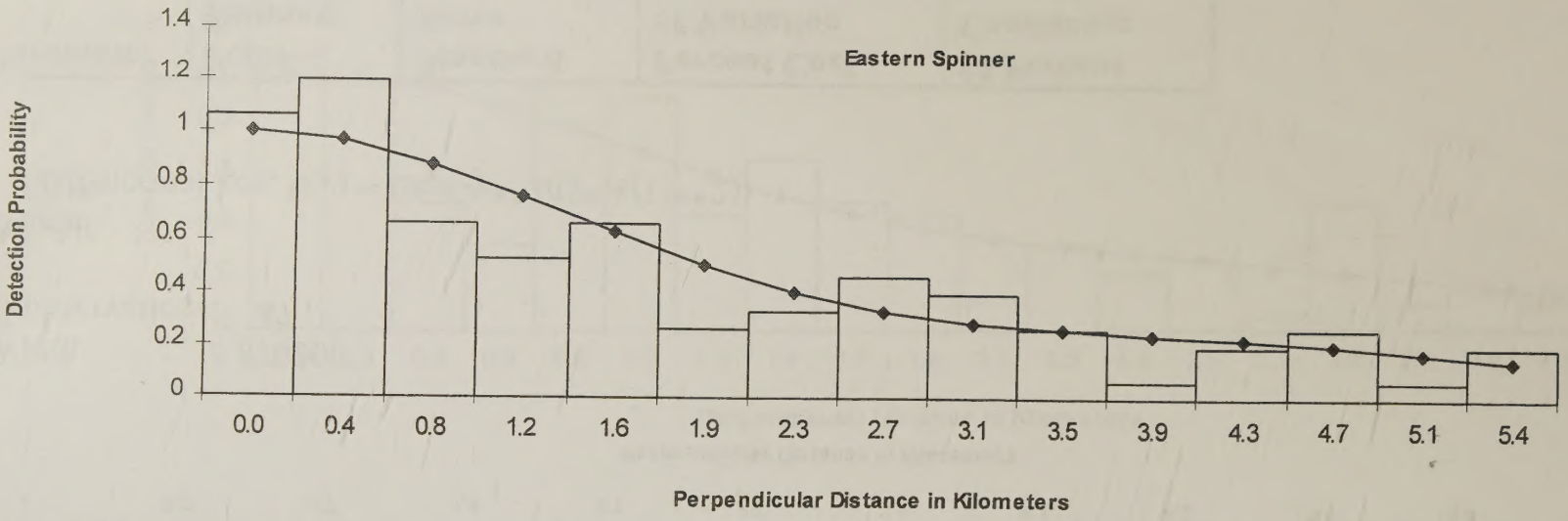
Fig. 6. Estimated detection function for eastern spinner dolphins in all strata.

Width : 5.830000



observations: 100

Model

Half-normal key, k(y) = Exp(-y**2/(2*A(1)**2))

Cosine adjustments of order(s) : 2

Parameter	Point Estimate	Standard Error	Percent Coef. Of Variation	95 Percent Confidence Interval
A(1)	2.781	0.2665	9.58	0.31099 0.48463
A(2)	0.3027	0.1297	42.85	
f(0)	0.3882	0.43529E-01	11.21	

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